Computer Aided Function-Allocation Evaluation System

CAFES

EXECUTIVE SUMMARY

DEFENSE TECHNICAL INFORMATION CENTER

Information for the Defense Community

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CREW SYSTEMS TECHNOLOGY
BOEING AEROSPACE COMPANY
D180-18577-1
JANUARY 1975

CAFES

A COMPUTER SYSTEM TO AID IN HUMAN FACTORS ENGINEERING FUNCTIONS FOR DESIGN, DEVELOPMENT, AND OPERATIONS OF MAN-MACHINE SYSTEMS.

SPONSORED BY THE NAVAL AIR SYSTEM COMMAND AND THE NAVAL AIR DEVELOPMENT CENTER

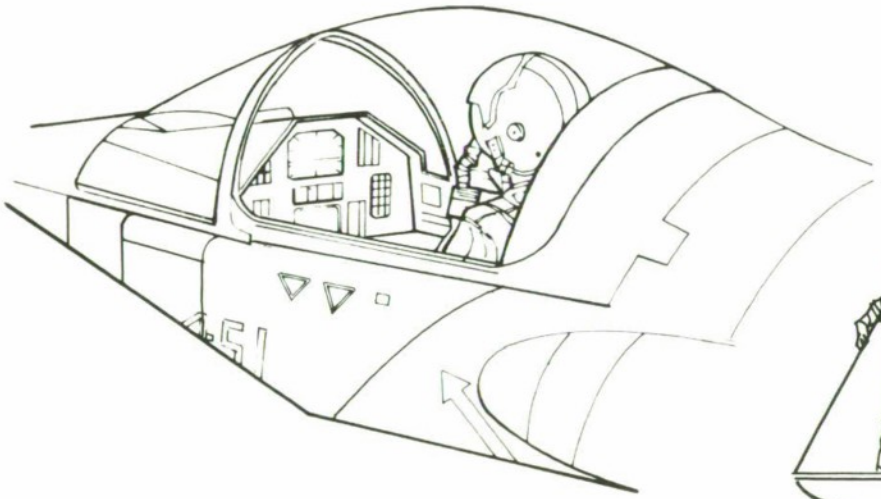
During system development, operations, or modifications, many program management decisions must be made without adequate back-up data. This brochure describes a system for improving availability of human factors data for management decisions necessary to optimum system development.

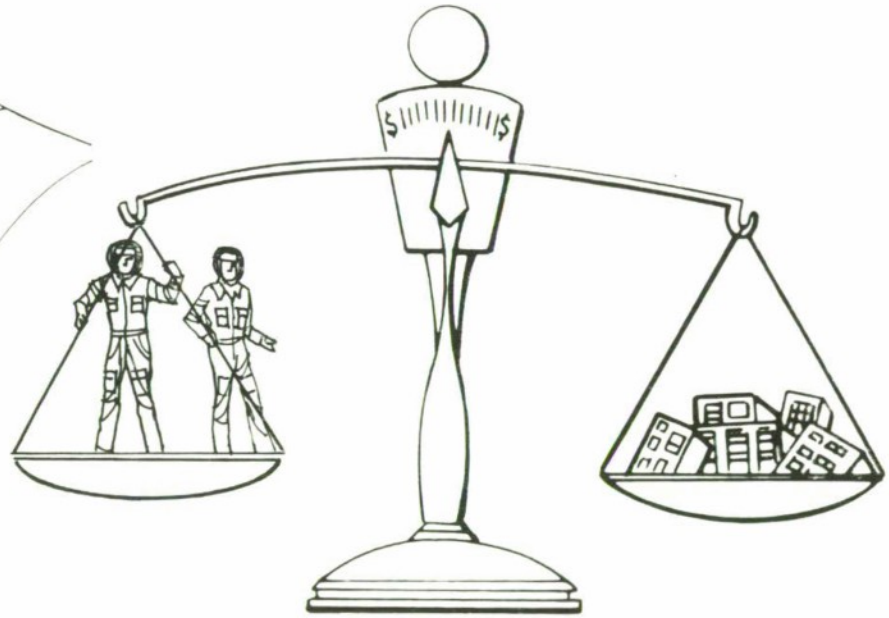
Rapidly advancing system technology demands more effective ways of evaluating crew capabilities with alternative display-control concepts, levels of automation, manning and training. Earlier and more extensive application of crew performance data over the system life cycle is needed to improve total system effectiveness. Projected impact on long range costs of system operation should also be considered.

CAFES

An Optimum Mix of Man/Machine Functions

MAN-MACHINE TRADEOFFS





- PERFORMANCE
- COST
- AVAILABILITY
- TRAINING
- RELIABILITY
- WEIGHT

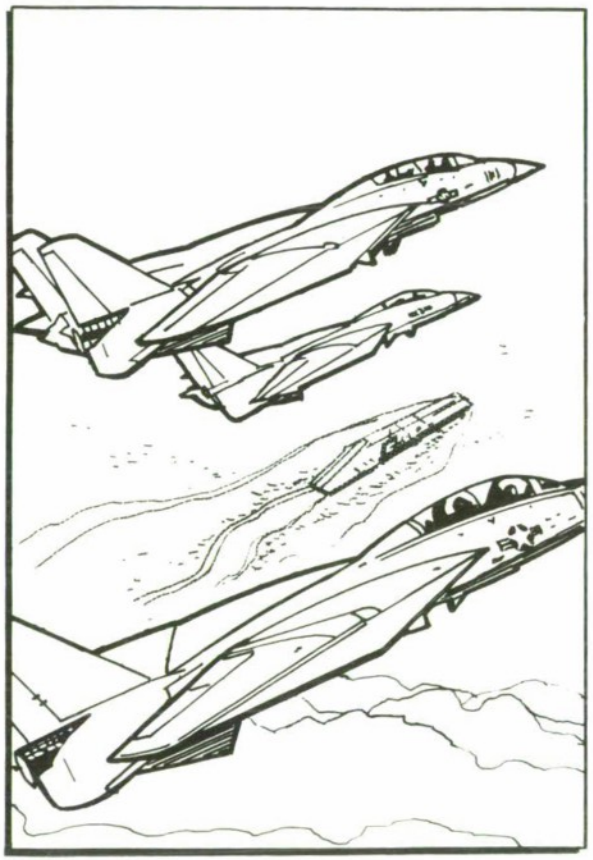
VS.

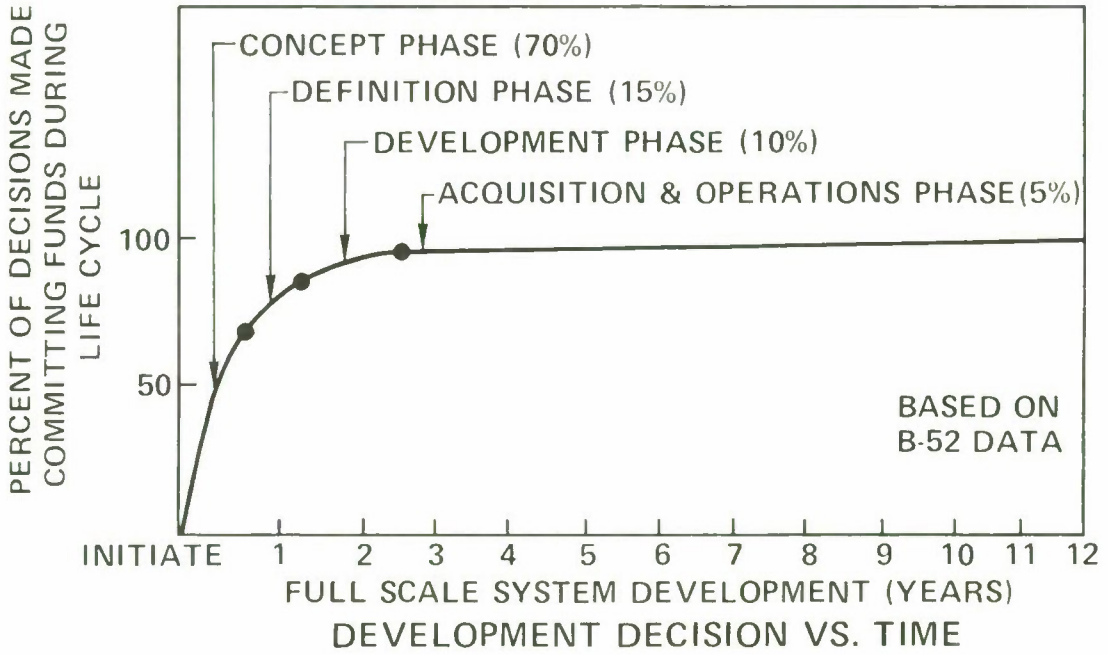
- PERFORMANCE
- COST
- AVAILABILITY
- COMPLEXITY
- RELIABILITY
- WEIGHT

Major program decisions made in very early phases of a program usually commit about 85% of life cycle costs. Many such decisions dictate major elements of final system design and resulting operational effectiveness, manning levels and training requirements throughout the system lifetime. Therefore, early human factors data reflecting the impact of these decisions is desirable. Often the decisions are made with minimum information on man-machine interface requirements and associated performance capabilities.

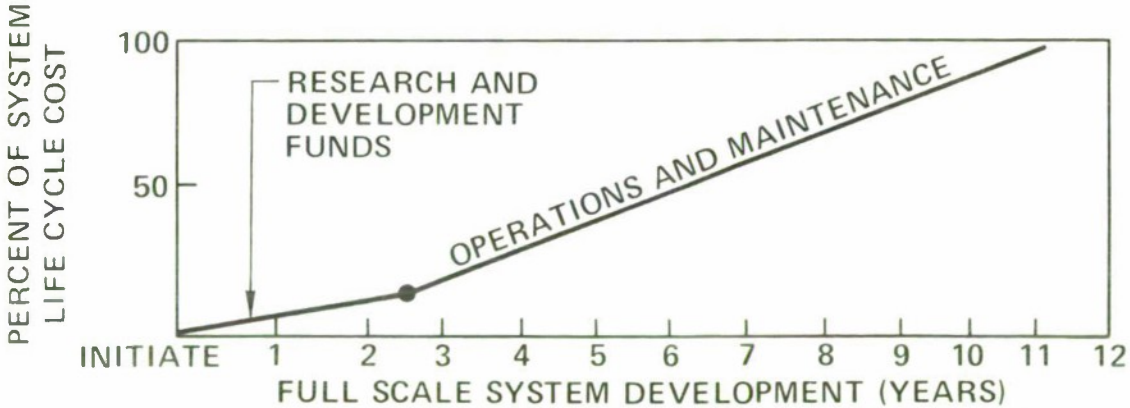
Over and above increased operational costs affected by early decisions, accidents causing death and injury through poor system design clearly establishes the need to improve Human Factors Engineering. For example, Naval Safety Center data (mid-1969 through early 1974) show that crew station factors were causal or contributory in destruction of 228 aircraft. Such statistics emphasize the need for more effective application of Human Factors Engineering techniques and principles.

Decision Influence on Total System Cost





DEVELOPMENT DECISION VS. TIME



LIFE CYCLE COST EXPENDITURES VS. TIME

Even very early program decisions involve many Human Factors aspects. The scope of crew operations may range from simple tasks through complicated command and control activities involving accurate appraisals, decisions and operations functions. Representative questions include: What CREW SIZE? What SKILLS? How much AUTOMATION? What type of CONTROLS-DISPLAYS? How EFFECTIVE will the crew be? Can the crew handle the WORKLOAD? What CREW STATION DIMENSIONS? How do crew anthropometric dimensions and requirements interact with DESIGN LAYOUT? Manual Human Factors Engineering techniques are cumbersome, time-consuming methods of answering the large number of questions that are typically raised.

The scope and complexity of the Human Factors Engineering tasks require extensive effort to produce all needed data and to be effective in system development. The Human Factors Engineer (HF Engineer) must correctly anticipate and resolve the full range of potential crew problems thoughout the system. He must perform detailed evaluations of crew interactions and constraints for all equipment interfaces, and then contribute to solutions that maintain system capability. System development experience has exposed deficiencies in Human Factor efforts to produce comprehensive, timely data which fully satisfies development needs.

Common Human Factors Engineering Developmental Problems

BREADTH OF SCOPE

- DOWNSTREAM TOTAL SYSTEM IMPACT OF DECISION
- ALL MAN-MACHINE INTERACTIONS
- INTEGRATION OF COMPLEX RATIONALE, ASSUMPTIONS AND FORECASTS

COMPLEX TASKS

- LABORIOUS MANUAL METHODS
- DIFFICULT DATA RETRIEVAL
- DIFFICULT INTEGRATION OF QUALITATIVE AND QUANTITATIVE DATA
- EXCESSIVE TIME FOR COMPREHENSIVE ANALYSIS OF RESULTS
- SLOW TURN-AROUND FOR SHIFTING SYSTEM ASSUMPTIONS AND DATA
- INCONSISTENT USE OF METHODOLOGIES FOR SIMILAR PROBLEMS
- NEW OR UNUSUAL SYSTEM REQUIREMENTS
- LACK OF DATA

LIMITED RESULTS

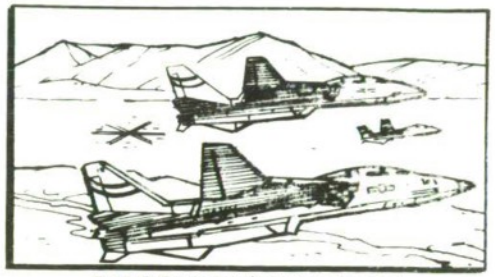
- LATE DATA
- LIMITED SCOPE
- INADEQUATE DEPTH FOR MANAGEMENT DECISIONS AND DEVELOPMENT NEEDS

Analytic time required to cover the range of information and level of detail for adequate design decision data is often incompatible with the system design and development schedule. However, many elements of Human Factors Engineering technology involve routine data retrieval and manipulation. Computer technology can be applied to expedite such analyses.

Recognizing the practical need for such technology improvement, the Naval Air Systems Command and the Naval Air Development Center sponsored development of computer aids for the HF Engineer. Produced by The Boeing Company, the Computer Aided Function-Allocation Evaluation System (CAFES) provides a means for the HF Engineer to enhance and expedite his design/development activities in any system development.

CAFES is applicable to any and all man-machine systems even though initial development has been based on aircraft systems. CAFES models can be applied to developing new systems, modifying existing systems or resolving operational problems.

CAFES Human Factors Engineer-Computer Interaction Concept



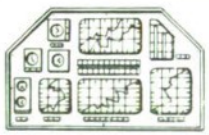
MISSION/SYSTEM REQUIREMENTS

FUNCTION ALLOCATION

TASK TIMELINE ANALYSIS

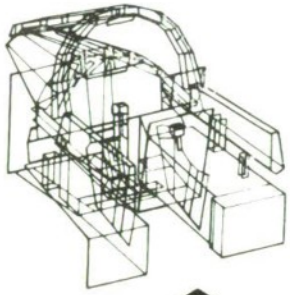
WORKLOAD ANALYSIS

COCKPIT LAYOUT/ EVALUATION

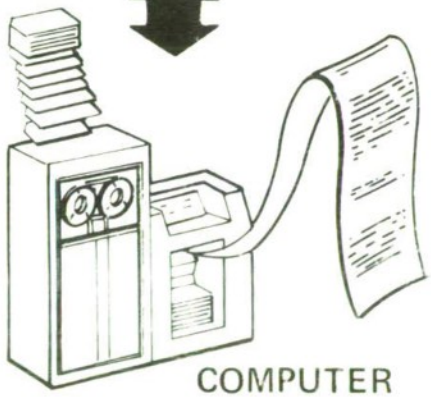


HUMAN ENGINEERING METHODS

DESIGN APPLICATION

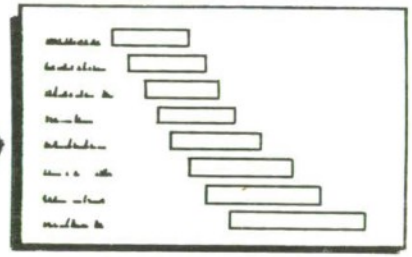


HUMAN FACTORS ENGINEER



COMPUTER

RESULTS IN



EFFECTIVE OUTPUTS

OPTIMUM CONFIGURATION

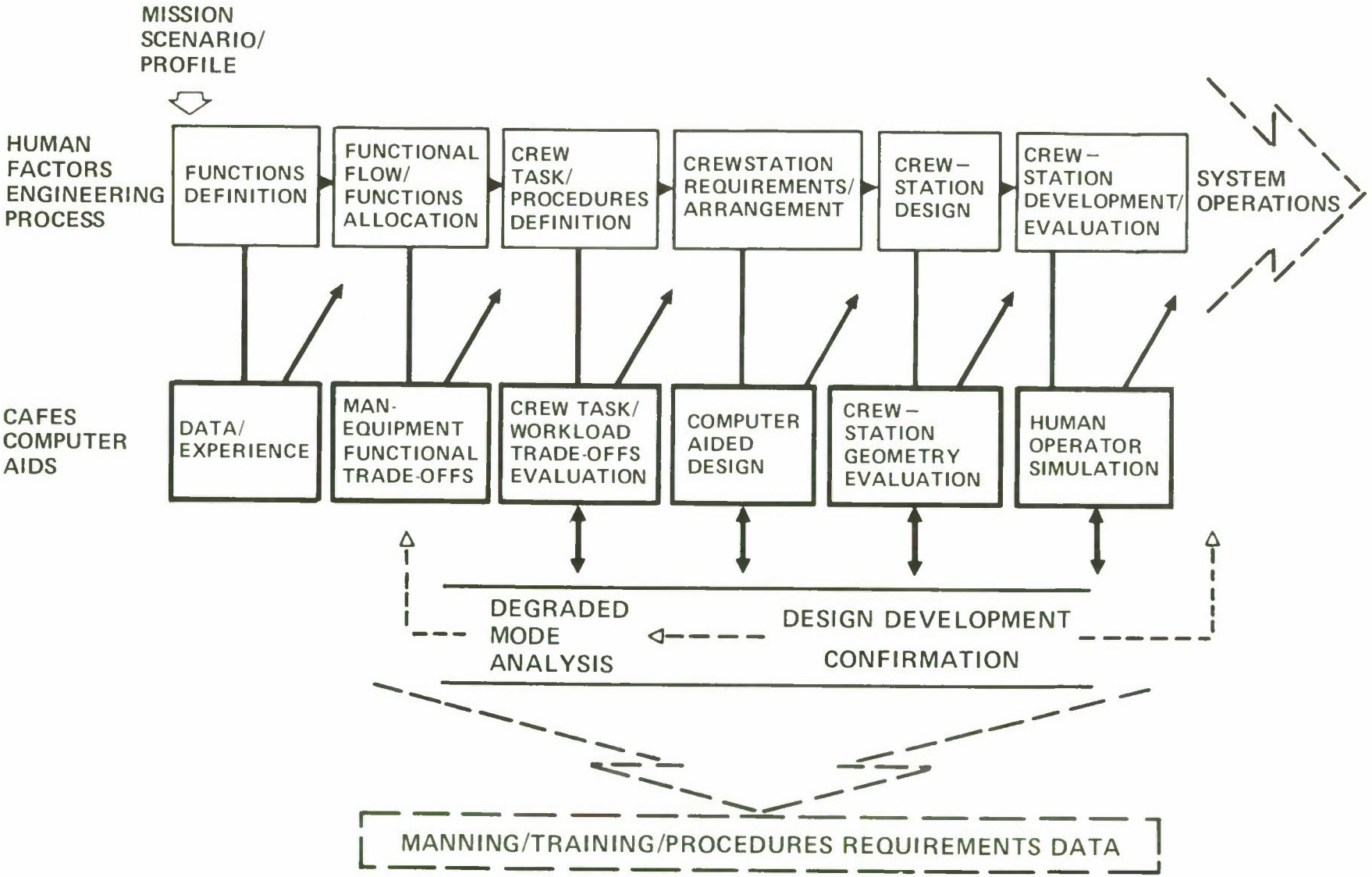
AND IMPROVED SYSTEMS PERFORMANCE

An overview of major HF Engineering tasks indicates a number of areas where the computer can be used to expedite these tasks. With its storage, retrieval, processing, and presentation capability, the computer can be of assistance from the earliest retrieval of existing data on related missions and systems experience. The computer can serve through all Human Factors development task phases, including evaluations of cockpit geometry, crew anthropometry and predictions of man-machine performance.

Computer utility is enhanced in view of the phasing of the Human Factors process. Since the data outputs from one phase relate to input requirements for the next, computer processing can assure that input-output formats are compatible. This will expedite the process for both initial system development and changes in system concepts.

Finally, the structured format that is required for computer processing provides visibility on the impact of system changes. More consistent HF Engineering analyses and trade-off considerations are also provided along with a systematic record of system development data.

Overall Crew System Development Process



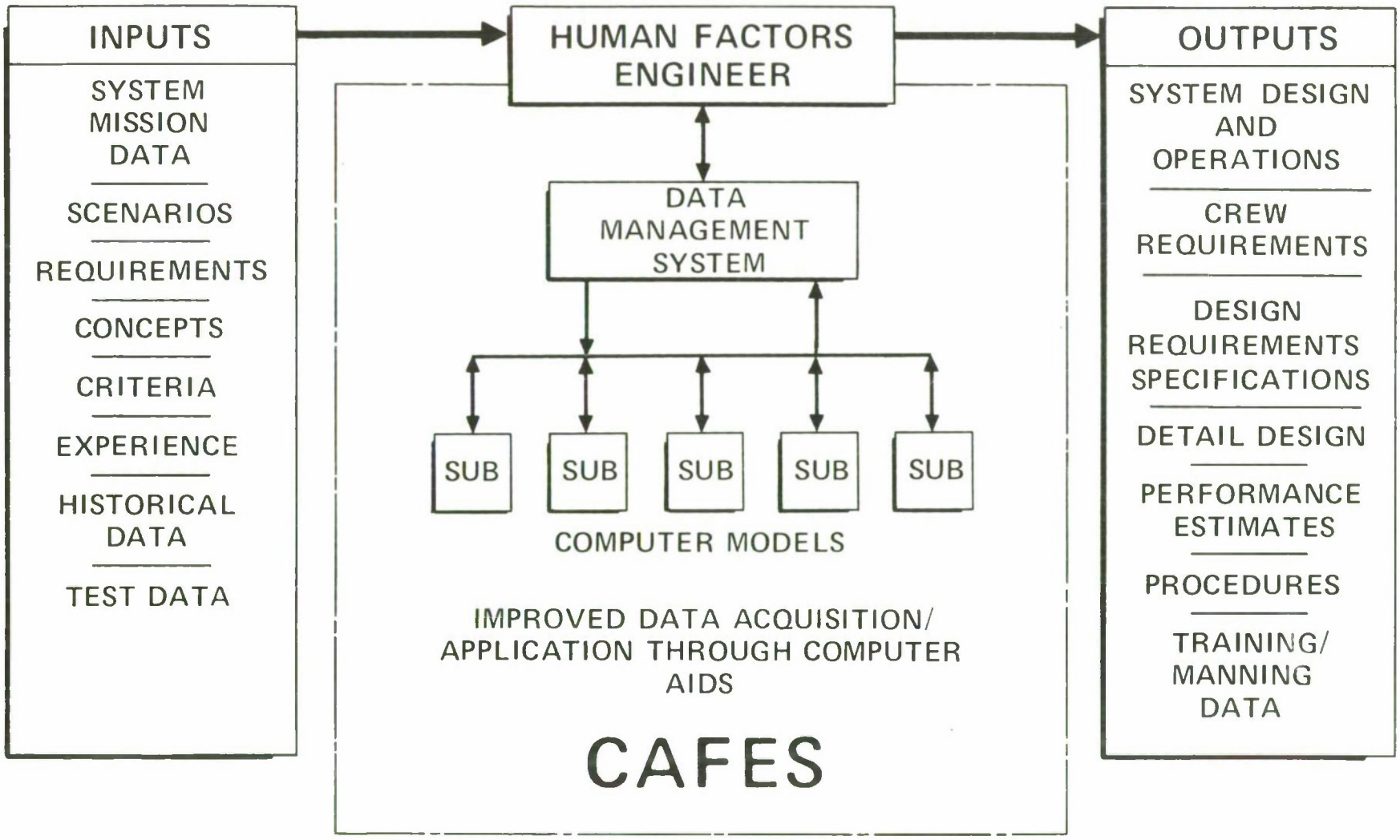
CAFES is a series of data processing aids enhancing the use of HF Engineering data to make program decisions. It is designed as a group of computer models to aid the HF Engineer in all facets of his program support activity. It facilitates his efforts by performing routine operations that would otherwise involve laborious and time consuming manual processes (data retrieval, organization, processing, presentation and storage).

Model design and application provides necessary visibility of processes for the HF Engineer to make informed judgements without becoming involved in tedious calculations. This frees him to spend more time on unique system requirements and on those development efforts that require creative use of professional knowledge and skills.

CAFES does not perform without the HF Engineer as the data reviewer, decision maker and source of instructions. Computer capability and speed aid him in expediting the HF Engineering process and computed results are clearly reported.

The interface between the HFE Engineer and CAFES is provided by a Data Management System (DMS). DMS functions as an executive to assess any of the other models independently, and as a central data system to access individual data items.

System Design Support With Computer Models



Through DMS, the user can work with any of the CAFES submodels or data elements. Models support his needs from initial data access through man-equipment trade-offs, workload appraisals; crew station layout development and geometry evaluations; and appraisals of human performance effectiveness.

Submodels can be used alone or in a cooperative state where data are exchanged between models. For example, task procedures data are produced by an early application of the Functions Allocation Model (FAM). These same data may be used as inputs to produce workload estimates in the Workload Assessment Model (WAM). Alternatively, task sequence data may be produced manually for WAM applications. The task sequence data are useful in establishing task-related equipment for crew station layout locations and are essential to the Crewstation Geometry Evaluation (CGE) computer model. In this model, an anthropometric man is processed through the tasks in a crew station in order to evaluate geometric relationships (access/interferences). Task sequence data also help structure the procedures needed for application of the Human Operator Simulator (HOS).

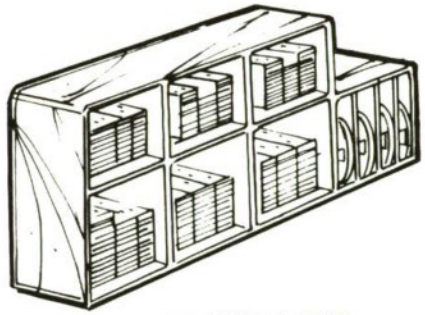
Individual CAFES submodels are illustrated on the following pages.

Cafes Capabilities Summary

HUMAN FACTORS ENGINEER (HFE)

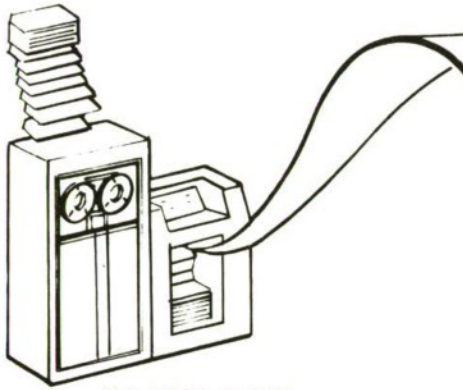
HFE PROCESS NEEDS	CAFES SUBMODELS
DATA • FLEXIBLE DATA STRUCTURE • EFFICIENT DATA RETRIEVAL AND USE	DATA MANAGEMENT SYSTEM (DMS)
MAN/EQUIPMENT TRADE-OFFS • BEST CREW SIZE & AUTOMATION LEVEL • OPTIMUM TASK ALLOCATION • EFFICIENT PROCEDURES DEVELOPMENT	FUNCTIONAL ALLOCATION MODEL (FAM)
WORK LOAD • CONFIRMED ALLOCATIONS • ADEQUATE PERFORMANCE TIME • DETAILED PROCEDURE ANALYSES	WORKLOAD ASSESSMENT MODEL (WAM)
CREWSTATION DESIGN • FEASIBLE STATION LAYOUTS • ADAPTABLE TO REQUIREMENTS, CONSTRAINTS, CRITERIA	COMPUTER AIDED DESIGN (CAD)
ANTHROPOMETRIC EVALUATION • CHECK PHYSICAL/VISUAL INTERFERENCES • VERIFY DETAILED CONFIGURATIONS	CREWSTATION GEOMETRY EVALUATION (CGE)
HUMAN PERFORMANCE EFFECTIVENESS • ESTIMATED HUMAN PERFORMANCE • BEHAVIORAL FACTORS, OPERATING ENVIRONMENTS, AND OPERATOR CHARACTERISTICS	HUMAN OPERATOR SIMULATION (HOS)

Data Management System (DMS)



COMPUTER MODELS

DATA SOURCES (NEW AND REVISED)



COMPUTER

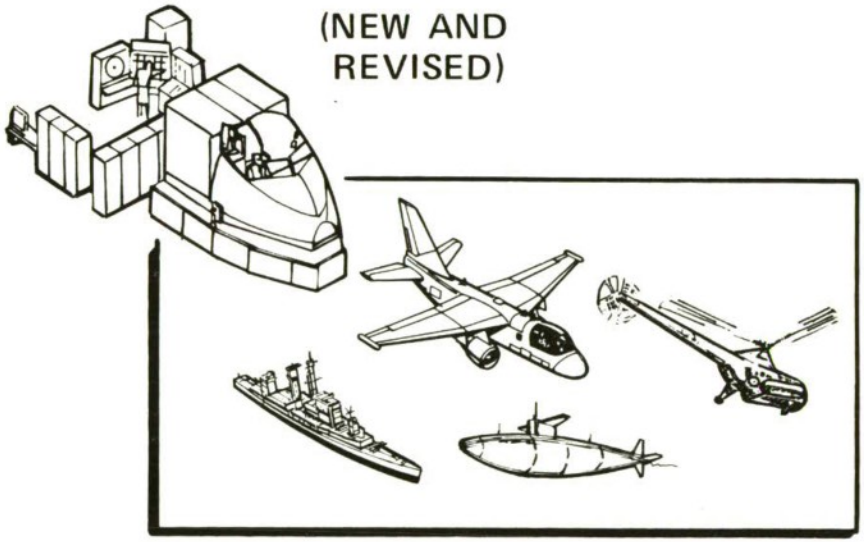
CAFE SUBMODEL REPORTS

FAM
WAM
CAD
CGE
HOS

TRADE OFF DATA

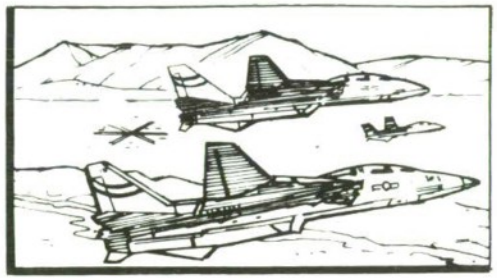
DATA REPORTS

DATA/REQUIREMENTS

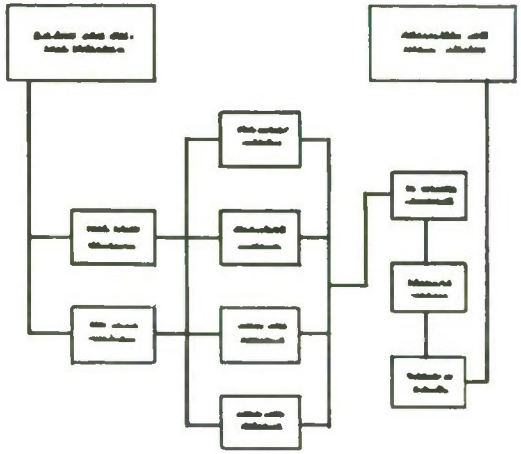


HUMAN FACTORS ENGINEER

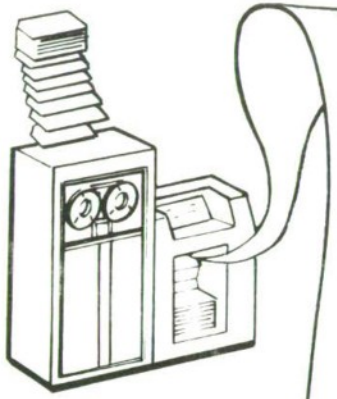
CAFES Function Allocation Model (FAM)



MISSION/SYSTEM REQUIREMENTS



FUNCTIONS/TASK ANALYSIS



COMPUTER

HUMAN FACTORS ENGINEER

TASK SEQUENCING

TASK STATISTICS

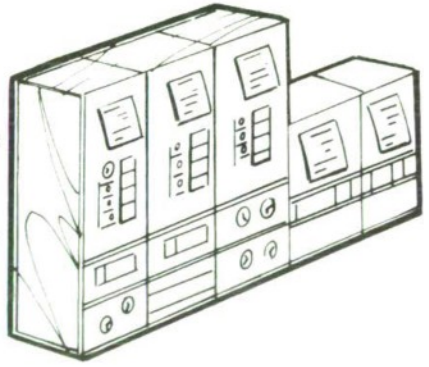
TASK SUCCESS EVALUATION

TASK ALLOCATION VERSIONS

MISSION SUCCESS EVALUATION

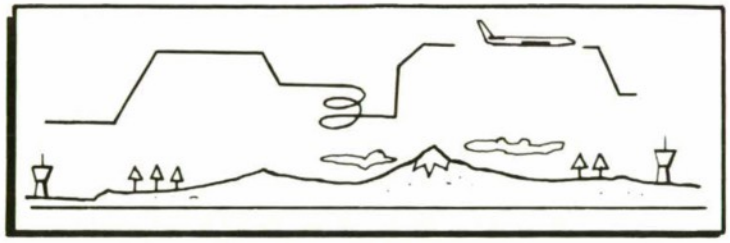
OPERATIONAL SEQUENCE DIAGRAM DATA

PROCEDURES

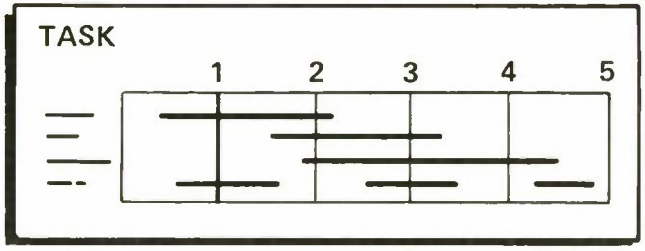


= MAN OR MACHINE

Workload Assessment Model (WAM)



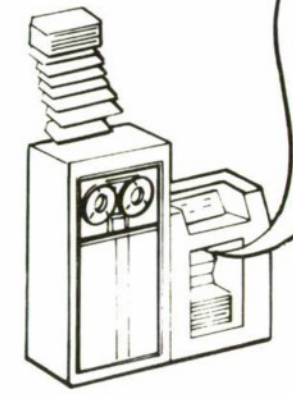
MISSION PROFILE



TASK TIMELINES

TASK TYPE	EYES	HANDS	FEET	COGNITIVE

SENSOR/MOTOR ANALYSIS

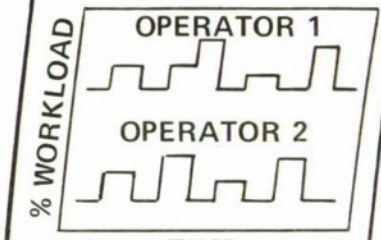


HUMAN FACTORS ENGINEER

CREW SIZE

WORK LOAD

COMPARISONS

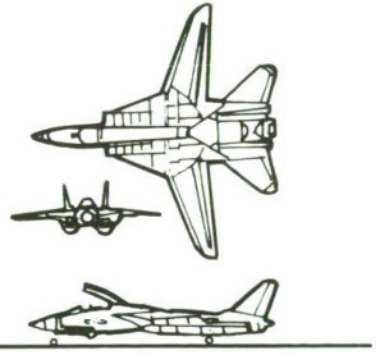


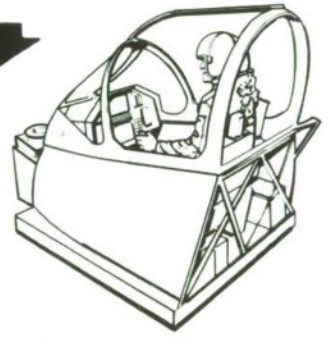
FLIGHT PHASE SUMMARY DATA

SUBSYSTEM CONTRIBUTION TO WORKLOAD

CONFIGURATION COMPARISON STATISTICS

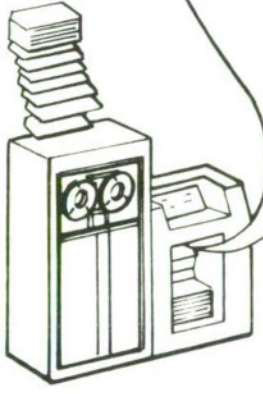
Computer Aided Design (CAD)





3-DIMENSIONAL CHARACTERISTICS

HUMAN FACTORS ENGINEER



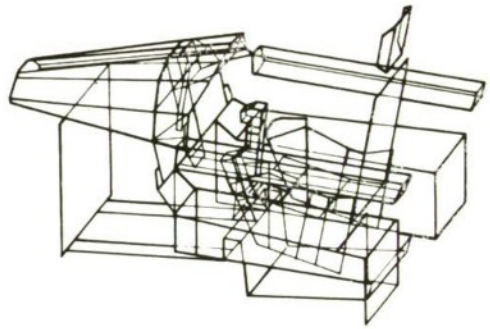
COMPUTER

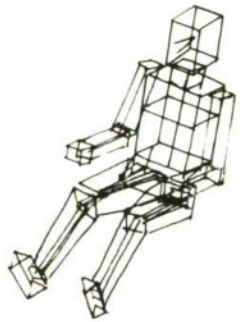
CREWSTATION DRAWINGS

Crewstation Geometry Evaluation (CGE)

ANTHROPOMETRIC MAN
(ALL PERCENTILE COMBINATIONS)

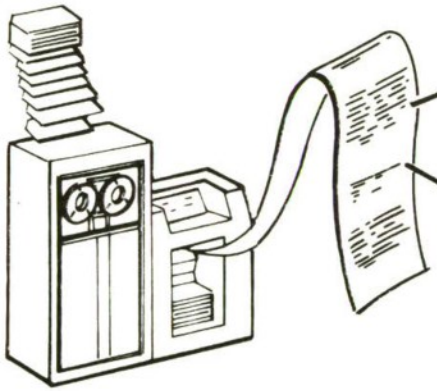
COCKPIT
DESIGN





TASKS TO PERFORM
- HAND TO STICK
- CHECK ALTIMETER
- SET AUTOPILOT

HUMAN FACTORS
ENGINEER

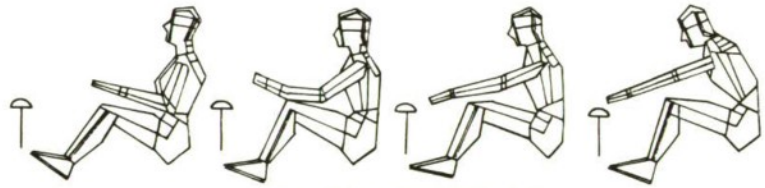


COMPUTER

DATA

GRAPHICS

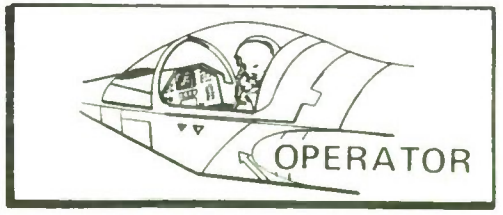
- REACH PROBLEMS
- PHYSICAL INTERFERENCE PROBLEMS
- VISUAL INTERFERENCE PROBLEMS
- SPECIFICATION COMPLIANCE



TASK MOTIONS

CAFES Human Operator Simulation (HOS)

SYSTEM REQUIREMENTS
- EXPERIENCE
- SIMULATION
- RESEARCH DATA



CAFES
SUBMODELS
DMS
FAM- WAM
CAD-CGE

HUMAN FACTORS ENGINEER

- DETAILED CONFIGURATION
- SPECIFIC PROCEDURES
- STIMULI DISPLAYS-CONTROLS
- PERFORMANCE SKILL-TRAINING MANIPULATION
- BEHAVIORAL DATA

PROCEDURE EXECUTION TIME
- OPERATION ACTION STATISTICS
- DETAILED TIME HISTORY
- OPERATOR DECISION ANALYSIS
- OPERATOR CAPABILITIES
- LIFE CYCLE CRITERIA

HUMAN OPERATOR SIMULATION

In summary, CAFES provides for a comprehensive and timely HF Engineering effort in system development and operations. It achieves this objective by helping to make early and effective program management decisions regarding Human Factors trade-offs. It contributes to improved design of man-machine interfaces, improved crew provisions, and improved crew performance in system operations.

CAFES is applicable for HF Engineering work across the full life cycle of a system. Applications range from early definition of requirements and functions through test and evaluation; operations; and system modifications. The computer records of rationale, assumptions, trade-offs and decisions will facilitate CAFES applications to a program.

Summary

MANAGEMENT BENEFITS FROM IMPROVED DECISION DATA WITH CAFES

- BETTER SYSTEM USE OF CREW IN TIMELY, WELL-FOUNDED, EFFECTIVE HUMAN FACTORS DATA
- IMPROVED APPLICATION OF MAN-EQUIPMENT SYSTEM TECHNOLOGY
- IMPROVED DECISION DATA FOR TRADE-OFFS OF SYSTEM PERFORMANCE, CREW PERFORMANCE AND LIFE CYCLE OPERATIONS

SYSTEM BENEFITS FROM IMPROVED CREW PROVISIONS/PERFORMANCE WITH CAFES

- BETTER MISSION CAPABILITY/EFFECTIVENESS
- IMPROVED OPERATION AND MAINTENANCE FEATURES
- MORE EFFECTIVE SAFETY FEATURES
- MORE CLEARLY DEFINED TRAINING, MANNING AND PROCEDURES DATA

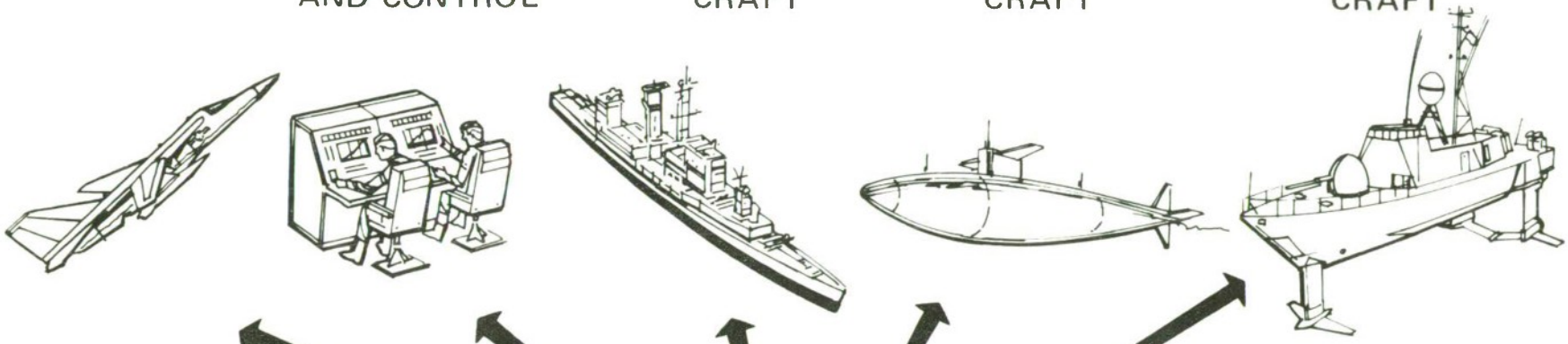
HUMAN FACTORS ENGINEERING BENEFITS FROM GREATER EFFICIENCY WITH CAFES

- EARLY/TIMELY PRODUCTS
- EFFECTIVE DATA APPLICATION/HUMAN PERFORMANCE ESTIMATES FROM EARLY CONCEPTS THROUGH OPERATIONS
- RAPID/COMPREHENSIVE ACCESS TO DATA
- MEANINGFUL DATA INTEGRATION/APPLICATION
- RAPID TURN-AROUND FOR SYSTEM CHANGES

Any manned system is controlled by the crew in the system and the crew must perform effectively or mission success will be compromised. CAFES can be used to improve any man-machine system and it helps in the realization of optimum system performance. It will directly support the Human Factors Engineering process and will provide an impetus for basic and applied research.

CAFES Multiple Utilization and Application for all Navy Systems/Operations

AIRCRAFT | COMMAND AND CONTROL | SURFACE CRAFT | SUBMERGED CRAFT | HYDROFOIL CRAFT



EXPLORATORY DEVELOPMENT

HUMAN FACTORS RESEARCH

MAINTENANCE SYSTEM REQUIREMENTS AND DESIGN

HFE
CAFES

CENTRAL DATA SOURCE

ADVANCED DEVELOPMENT

TEST PROGRAM DESIGN AND EVALUATION

TRAINING SYSTEM REQUIREMENTS AND DESIGN

Development of CAFES is proceeding according to the program schedule. The process of refinements and application is continuous and whenever possible, models are applied to on-going programs. CAFES models have already been applied to several military systems studies.

Current documentation may be obtained from the Naval Air Development Center/Code 402 or from The Boeing Company. Models will be implemented at the Naval Air Development Center upon completion of the CAFES development program.

Cafes System Development Schedule